Amendments to the Specification:

Please replace the paragraph beginning at page 1, paragraph [0001] with the following amended paragraph:

This application is a continuation of U.S. Patent Application no. 10,142,646, filed May 8, 2002 now abandoned. U.S. Application No. 09/803,268, now U.S. Patent No. 6,612,160, has overlapping subject matter, including the same title and with some of the same claims, but different inventorship.

Please replace the paragraph beginning at page 13, paragraph [0019] with the following amended paragraph:

FIGURE 1D is a front elevational view illustrating parasitic motion of a piezoelectric actuator assembly configured to move in a predetermined direction, in this case "Z";

FIGURE 2 is a side elevational view of a scanning probe microscope assembly according to the present invention;

Please replace the paragraph beginning at page 15, paragraph [0030] with the following amended paragraph:

[0030] At a lower free end 105 of actuator assembly 104, a probe assembly 113 is attached and includes a cantilever 114

having a stylus 115 attached thereto. During operation, stylus 115 is scanned across the surface of sample 108 to determine surface characteristics (e.g., topography) of the sample. The scanning operation is provided by actuator 110, which is ~~11~~ driven by program-controlled signals (e.g., appropriate voltages) to cause the actuator 110 to move laterally in two dimensions across the surface of sample 108, as well as to extend and retract the probe assembly 113, i.e. to move cantilever 114 toward or away from the sample, typically in response to closed loop signals derived from sensor 109. As a result, the actuator 110 preferably can translate the cantilever 114 in three orthogonal directions under program control. Note that for convenience we will refer to the extending and retracting of the probe assembly 113 toward and away from sample 108 as motion in the Z direction, and translation laterally across the surface of the sample as motion in the X direction and the Y direction, where the X and the Y axes are orthogonal to each other ~~10~~ <u>and</u> define a plane substantially parallel to the surface of sample 108. The nomenclature is used purely for convenience to indicate three orthogonal directions.

Please replace the paragraph beginning at page 16, paragraph [0031] with the following amended paragraph:

[0031] Next, to illustrate different aspects of the preferred embodiment, we initially turn FIGURE 3, which shows a measuring apparatus for monitoring movement of a piezoelectric Z tube ~~222~~ 111 of an actuator 110. An optical measuring device 120 includes a steering mechanism 122 and couples actuator 110 to a reference frame 124, the frame being fixed relative to actuator 110. In addition, steering mechanism 122 acts as a probe support assembly to which a probe assembly (not shown) is attached. In operation, a beam of electromagnetic radiation, such as light "L", is generated by a light source 126 and is directed at steering mechanism ~~121~~ 122. Steering mechanism 122 changes the direction of the light beam in response to movement of actuator 110. This change is detected by a detection sensor 128 and, because in this case tube ~~222~~ 111 is a Z tube, the change in direction of the beam is indicative of vertical actuator movement. More particularly, steering mechanism 122 includes a movable bar assembly having a coupling bar or first link 130 having a first end attached to Z tube ~~222~~ 111 and a second end 132. Steering mechanism 122 also includes a movable bar or second link 134 having opposed ends, the first of which is rotatably attached to the second end 132 of link 130 at a first pivot point 133. The opposite end of the movable bar 134 is rotatably attached to fixed reference frame 124 at point 136. Movable bar 134 defines a surface 138, which is adapted to

reflect light beam "L." A second reflecting surface preferably comprises a fixed mirror 140 attached at an angle to an inner surface 142 of fixed reference frame 124 to deflect incoming light beam "L" towards movable bar 134. Moreover, to accommodate the light beam, fixed reference frame 124 includes a first aperture 144 adapted to receive the incoming light beam, and a second aperture 146 adapted to allow passage of the beam, after being reflected by bar 134, through fixed reference frame 124 and towards detector. In operation, in response to actuation of actuator 110 (for example, in the Z direction marked "A" in FIGURE 3), movement of the actuator is transferred to movable bar 134 via coupling bar 130. This causes the movable bar 134 to rotate generally in a clockwise fashion about second pivot point 136. As a result, the steered beam is deflected towards detector 128 at an angle different than when Z tube 222 is not actuated. This change in the direction of the light beam "L" is depicted by the path marked "B" in FIGURE 3 and is indicative of the amount of actuator movement. More particularly, as the actuator 110 is used to move the probe (not shown, but preferably coupled to a bottom surface 139 of movable bar 134) in the Z direction, the amount of movement in the Z direction is sensed by the system by noting the position at which the deflected light beam contacts the sensor 128.

Please replace the paragraph beginning at page 19, paragraph [0033] with the following amended paragraph:

[0001] ~~[0033]~~ Measuring device 150 also includes a lens 158 that is coupled to Z tube 156. Notably, light source 126 is positioned such that lens 158 is intermediate the light source and a sensor 128 disposed at a position generally opposite the light source 126. In operation, as Z tube 156 is actuated and caused to move in a particular direction (in this case "Z"), lens 158 correspondingly moves. Because sensor 128 is fixed, as is light source 126, measuring the position at which the light beam "L" output by lens 158 contacts sensor 128 is indicative of the movement of the actuator 152~~1~~. Preferably, the magnification of the lens equals,

$$M=1 + i/o \qquad \textit{Eqn. I}$$

where "i" is the orthogonal distance from sensor 128 to lens 158, and "o" is the orthogonal distance from lens 158 to light source 126.

Please replace the paragraph beginning at page 20, paragraph [0034] with the following amended paragraph:

[0002] [0034] Turning to FIGURE 3B, light source 126, rather than the lens 158 as in FIGURE ~~20~~ 3A, is mounted to the actuator 152 whose movement is to be measured (in this case the "Z" actuator 156). In this embodiment, a measuring device 151 includes light source 126 attached to actuator 156 via a mount 162, and a sensor 128 is included which is fixed ~~14~~ relative to the actuator 152 and the light source 126. In addition, a lens 164 is positioned intermediate light source 126 and sensor 128 and has a magnification generally equal to,

$$M = i/o \qquad \textit{Eqn. 2I}$$

where "i" is the orthogonal distance between lens 164 and the sensor 128, and "o" is the ~~5~~ orthogonal distance between light source 126 and lens 164. As the Z tube is actuated, light source 126 moves in conjunction with it, thus causing light passing through lens 164 to be directed at a point displaced from the point at which the light is directed on sensor 128 when Z tube 156 is not actuated. Sensor 128 detects this displacement and generates a corresponding signal indicative of the amount of actuator 156 movement.

Please replace the paragraph beginning at page 22, paragraph [0036] with the following amended paragraph:

[0036] Turning to FIGURE 4, an apparatus 200 is illustrated for ensuring that displacements generated by an actuator, and transferred to the cantilevered probe coupled thereto, are isolated from movement of the actuator in a direction other than the intended direction of the actuator, e.g., isolated from parasitic movement of the actuator. Generally, an actuator 110 is coupled to a flexure 204 via a flexible bar or member ~~(i.e~~ i.e., a coupling) 206 that is adapted to transmit displacement only in an intended direction, thus minimizing adverse affects associated with parasitic movement of the metrology apparatus, such as actuator 110. In ~~Figure~~ FIGURE 4, for example, actuator 110 is preferably a Z tube actuator. Therefore, in that case, coupling 206 is configured so as to transmit displacement generated by actuator 110 in the Z direction, but generally not in the X and Y directions. Note that the remaining discussion of ~~Figure~~ FIGURE 4 assumes actuator 110 is a ~~Z-tube~~ Z tube actuator.

Please replace the paragraph beginning at page 22, paragraph [0037] with the following amended paragraph:

[0037] Next, apparatus 200 includes a fixed reference structure 208 to which flexure 204 is also attached. Flexure 204 is preferably a parallelogram flexure comprising a four bar linkage that is adapted to translate so that its opposed vertical links 210, 212 remain generally orthogonal to the X-Y plane in response to force and therefore displacement transmitted in the vertical or "Z" direction by bar 206. This movement of flexure 204 is rotation about points 215, 216, 217, and 218 thereof, as described in further detail below in conjunction with FIGURE 7.

Please replace the paragraph beginning at page 23, paragraph [0038] with the following amended paragraph:

[0038] Again, to ensure that the opposed vertical links of the flexure 204 move in this fashion, the flexible element 206 is configured so as to be sufficiently rigid to transmit vertical displacements of actuator 110, but flexible enough to decouple, for example, the parasitic X-Y movement of the actuator 110 from the flexure 204. Flexible element 206 may be on the order of 3 mm long and 0.2 mm in diameter, for instance. A probe 214 is coupled to link 210 of flexure 204. As a result, probe 214 of the SPM moves substantially only in the intended

direction in response to activation of actuator 110, in this case the Z direction. Because in a preferred embodiment reference structure 208 is coupled to an X-Y actuator assembly (e.g., 220 in FIGURE 5), reference structure 208 moves in conjunction therewith, thus transmitting this intended X-Y motion to flexure 204. As a result, probe 214 can move in the X and Y directions. Notably, this intended X-Y motion is not inhibited by bar 206 because bar 206 is generally flexible in response to displacements directed in the X and Y directions. Such a decoupling arrangement is employed in the AFM shown in FIGURES 2, 5, and 7, and therefore a more specific description of the apparatus and its operation is provided in conjunction therewith immediately below.

Please replace the paragraph beginning at page 25, paragraph [0041] with the following amended paragraph:

[0041] Still referring to FIGURES 2 and 7, to monitor, for example, topographical changes on the surface of the sample and provide appropriate feedback depending on the mode of SPM operation, an electromagnetic radiation source 107 (shown in ~~Figure~~ FIGURE 2) is fixed to support 102. Source 107 generates radiation that is directed through actuator 110 towards a mirror 117 supported by a surface of cantilever 114 of probe assembly

113. Mirror 117, in turn, directs the radiation toward detector 109 (shown in ~~Figure~~ FIGURE 2). Mirror 117 may, in the alternative, be a polished portion of the back (upper) side of the cantilever 114. Detector 109 receives the light reflected from probe 114 and, in turn, generates a signal indicative of, for example, the deflection of probe 114, as is conventional in the art.

Please replace the paragraph beginning at page 25, paragraph [0042] with the following amended paragraph:

[0042] The entire actuator assembly 104 is shown in more detail in FIGURE 5. Again, actuator assembly 104 includes actuator 110 (preferably a piezoelectric tube) and reference assembly 111 which in turn comprises reference structure 112, coupling mount 228, flexible bar coupling 230, flexure 232, and slotted disk 250 as described in detail below. In this preferred embodiment, actuator 110 is formed of two sections; first, an upper section 220 that is configured to deflect laterally in a plane lying perpendicular to the axis of the actuator under program control. For this reason it is termed an X-Y tube. The actuator 110 also includes a lower Z tube actuator 222 which is adapted to extend or retract in a direction substantially parallel to the longitudinal axis of the tube under program

control. A discussion of a means for controlling such actuators can be found, for example, in U.S. Patent No. 6,008,489 and other related applications.

Please replace the paragraph beginning at page 26, paragraph [0043] with the following amended paragraph:

[0043] The two tubes 220, 222 of the piezoelectric actuator 110 are coupled together ~~end to end~~ end-to-end proximate to a circular collar 224 that extends around and is fixed to the ~~actuator110~~ actuator 110. Also, the assembly 104 is preferably coupled to frame 102 (FIGURE 2) of the scanning probe microscope with a flange 226 that is fixed to the top of X-Y tube 220. In this preferred embodiment, tubular member or elongate reference structure 112 of reference assembly 111 extends around at least the Z tube 222 of the actuator 110 and is fixed to collar 224. Collar 224, in turn, is fixed to the actuator 110 at or near the junction of the upper and lower actuator sections. When X-Y tube 220 is driven under program control, it deflects in a direction generally perpendicular to the longitudinal axis. Since collar 224 and hence structure 112 are fixed to the actuator near the bottom of X-Y tube 220, they also deflect laterally.

Please replace the paragraph beginning at page 27, paragraph [0046] with the following amended paragraph:

[0046] Referring again to FIGURE 7, the lower end of flexible bar coupling 230 is fixed to the probe support assembly or flexure 232 of reference assembly 111. Flexure 232 is preferably formed out of a solid block of material, and comprises aluminum or a similarly light alloy. The flexure 232 is generally in the form of a movable bar assembly or four bar linkage. These links are ~~ide ntified~~ identified in FIGURE 7 as 232A, 232B, 232C, and 232D.

Please replace the paragraph beginning at page 28, paragraph [0048] with the following amended paragraph:

[0048] Link 232B is supported at flexible joints ~~233~~ 213 and 234 to links 232A and 232C ~~(3~~, respectively. Links 232A and 232C are coupled to link 232D at flexible joints or linkages 236, and 238, respectively. When link 232B is pulled upwardly (again in the direction marked "A") from a relaxed position as shown in phantom in FIGURE 7, links 232A and 232C are deflected upwardly at one end by link 232B. The other end of links 232A and 232C generally rotate about joints 236 and 238 (also shown in phantom).

Please replace the paragraph beginning at page 28, paragraph [0049] with the following amended paragraph:

[0049] Links 232A and 232C are preferably of generally equal length and are parallel to each other. Similarly, links 232D and 232B are preferably of equal length and parallel to each other. Link 232D is fixed to the lower end of structure 112. Because structure 112 does not translate upwardly or downwardly when Z tube 222 moves upwardly or downwardly (due to its connection to collar 224 fixed on actuator 110 above the Z tube 222) any expansion or contraction of Z tube 222 upwardly or downwardly causes the four bar linkage of flexure 232 to deflect about joints 233, ~~234~~ 213, 236 and 238. Preferably, thickness t1, of each of the links is approximately .9 mm, while the thickness t2 of each of the joints is approximately .08 mm.

Please replace the paragraph beginning at page 30, paragraph [0052] with the following amended paragraph:

[0052] More particularly, comparing the relaxed position of the flexure 232 in FIGURE 7 to the upwardly deflected position shown in phantom, it is clear that upward deflection of link 232B causes link 232C ~~47~~ to rotate about joint 238. This in turn causes mirror 242 to rotate about joint 238. This movement

of mirror 242 causes the light beam to reflect off mirror at a different angle than when the beam is reflected off the mirror 242 when the flexure is in the relaxed position. As a result, the beam moves to a position on the detector 128 which is displaced from the initial location of the beam, as shown in phantom. It is this change in the position of light impinging on detector 128 that causes a change in the signal generated by detector 128, and hence, provides an indication that link 232B has translated upwardly or downwardly with respect to the free end of structure 112 to which link 232D is fixed.

Please replace the paragraph beginning at page 32, paragraph [0055] with the following amended paragraph:

[0055] The above-described apparatus is thus used to isolate the movement of Z tube 222 in its intended Z direction, yet permit free lateral motion of the lower end 105 of actuator assembly 104. At the lower end of actuator assembly 104, reference assembly 111 includes slotted disk 250 having four mounting pins 252 (see FIGURE 6), the slotted disk being fixed to the lower portion of link 232B. Next, probe assembly 113 includes a probe base 101 (shown in FIGURE 7 in phantom lines) that can be plugged or unplugged from pins 252 to hold the probe base 101 onto the slotted disk 250. Probe assembly 113 also

includes a cantilever 114 fixed on one end to the probe base 101, and a stylus 115 attached to the free end of cantilever 114.

Please replace the paragraph beginning at page 32, paragraph [0056] with the following amended paragraph:

[0056] Referring again to FIGURES 2 and 7, light source 107 (shown in FIGURE 2) generates light which travels down through the actuator 110, and is reflected off mirror 117 and returns to detector 109 (shown in FIGURE 2). Whenever cantilever 114 is flexed upwardly or downwardly about its mounting point, mirror 117 rotates about the fixed end of cantilever 114 and causes the light generated by source 107 to move with respect to detector 109. This movement, in turn, causes a change in the signal generated by detector 109 that indicates a change in the amplitude of the deflection of cantilever 114, and hence a change in the force and/or distance relationship of the probe assembly 113 and the sample surface 108.

Please replace the paragraph beginning at page 35, paragraph [0060] with the following amended paragraph:

[0060] Referring to FIGURE 8B, in another alternate embodiment of a flexure for isolating "Z," similar to that shown in FIGURE 8A, a pair of cross wires 322, 324 disposed generally orthogonally to one other are attached at their opposed ends to a mounting ring 326 that, in turn, is attached to a reference structure (for example, 112 in FIGURE 8A). Again, a coupling element or member (230 in FIGURE 8A) is employed to couple actuator 110 to the junction of cross wires 322, 324. Moreover, a probe assembly is coupled to wires 322, 324 and thus moves in corresponding fashion with wires 322, 324.

Please replace the paragraph beginning at page 35, paragraph [0062] with the following amended paragraph:

[0062] Turning next to FIGURE 9, an alternative embodiment of the actuator assembly 104 of the present invention is shown. In particular, an actuator assembly 400 decouples X-Y movement (e.g., X-Y movement of an X-Y actuator 220) from the measurement of the amount of vertical movement produced by Z actuator 222. Actuator assembly 400 comprises an actuator 110 which in turn preferably comprises a piezoelectric tube actuator, a reference assembly 401, and a probe assembly (not shown). Moreover, piezoelectric tube

~~[0063]~~ actuator comprises X-Y tube 220 and Z tube 222.

Please replace the paragraph beginning at page 36, paragraph [0064] with the following amended paragraph:

[0064] Reference assembly 401 includes a circular mount 402 having a clamp 404 and a rod 406 having a longitudinal axis generally parallel to, and displaced from, the longitudinal axis of tube actuators 220, 222. Clamp 404 is employed to couple a first end 408 of rod 406 to a coupler 324 of actuator 220. A second end 410 of rod 406 is coupled to a flexure 412 of reference assembly 401. Flexure 412 is, in turn, coupled to a tube 222. Flexure 412 includes two joints 414, 416. In addition, mirrors 418, 420 are attached to flexure 412 such that their reflecting surfaces are generally orthogonal to one another, thus forming a structure akin to a corner-cube ~~retro-~~ retroreflector similar to that described above in conjunction with FIGURE 7. Preferably, reflecting elements 418, 420 are front surface mirrors.

Please replace the paragraph beginning at page 37, paragraph [0065] with the following amended paragraph:

[0065] In operation, a light beam generated by a source 126 is directed at mirror 420 which reflects the beam towards

mirror 418 which, in turn, reflects the beam towards detector 128 for measuring the amount of vertical deflection. As Z tube 222 is actuated, the portion of flexure 412 having mirror 410 on it rotates about joints 414, 416 such that mirror 418 reflects the beam at an angle indicative of the amount of the movement. Most notably, lateral movement of actuator 110 (for example, generated by X-Y tube 220) for scanning a sample (not shown) is decoupled from this Z measurement. In particular, rod 406 is independent of movement of the Z tube 222 because it is attached at clamp 404 at a point on actuator 110 above the top of Z tube 222. As a result, rod 406 moves when X-Y tube 220 is actuated, but not when Z tube 222 is actuated. When flexure 412 rotates about joints 416, 418 in response to vertical movement of Z tube 222, vertical movement of the probe can be accurately measured notwithstanding simultaneous movement caused by X Y tube 220. This is primarily due to the mirrors 418, 420 always generally maintaining their orthogonal relationship. As a result, the measurement of Z is isolated from X Y movement generated by tube 220.

Please replace the paragraph beginning at page 38, paragraph [0067] with the following amended paragraph:

[0067] Referring again to FIGURES 2 and 7, in one mode of operation, the stylus 115 is in contact with the sample, and slight deflections of the cantilever 114 caused by its moving ~~20~~ over the sample are measured. This is called "contact" mode. As the stylus 115 is deflected upwards, it moves cantilever 114 and mirror 117. This change in the position of mirror 117 causes the reflected light to move across detector 109 (shown in ~~Figure~~ FIGURE 2). The output of the detector 109 is fed back to the Z tube 222. Thus, flexing of the cantilever 114 is a function of the signal provided by detector 109. In typical operation, the amount of flexing of cantilever 114 is maintained constant by extending or retracting Z tube 222 (e.g., lengthening or shortening) in response to a signal based on the output of the detector 109. When the stylus 115 reaches a surface asperity that causes the cantilever 114 to flex upward, therefore deflecting light with respect to detector 109, the SPM attempts to restore the cantilever 114 to the same position on or above the surface of the sample. This capability is provided by data acquisition and control module 500 shown in FIGURE 10, that extends or retracts Z tube 222 in order to restore cantilever 114 to its original deflection.

Please replace the paragraph beginning at page 39, paragraph [0069] with the following amended paragraph:

[0069] Referring still to FIGURE 10, a control circuit 500 is shown connected to sections 220 and 222 of an actuator 110, such as a piezoelectric tube actuator, detectors 128 and 109, and sources 126 and 107. Control circuit 500 includes data acquisition and control module 502 which is coupled to and drives actuator drivers 504 and source drivers 506. Actuator drivers 504 are in turn coupled to tube actuators 220 and 222 of actuator 110. These drivers 504 generate high voltage signals necessary to cause X-Y tube 220 to move laterally and Z tube 222 to expand and contract vertically. Source drivers 506 are coupled to and drive radiation sources 126 and 107. Control module 502 is also coupled to and receives signals from detector signal conditioner 508. Signal conditioner 508 receives the raw signals from the two radiation detectors 128, 109 and converts them into signals that can be read by control module 502.

Please replace the paragraph beginning at page 43, paragraph [0073] with the following amended paragraph:

[0073] The preferred embodiment also avoids another positional error due to lateral deflection of Z tube 222 when it contracts or expands. It is important in most measuring processes to determine not only the height of the surface of

sample 108, but also the location at which that height measurement occurred. As we explained in the background of the invention, Z tube 222 undesirably deflects laterally when it contracts or expands. Without reference structure 112, this would cause the probe to steer slightly forward, backward, to the left, or to the right across the surface of the sample, rather than moving straight upwardly or downwardly. Link 232B, which translates upwardly and downwardly together with flexure 232 and the probe itself, is isolated from these lateral deflections of Z tube 222. It communicates only the expansion and contraction of Z tube 222 to the probe.

Please replace the paragraph beginning at page 44, paragraph [0074] with the following amended paragraph:

[0074] The four bar linkage of flexure 232 ensures that the probe itself can only translate upwardly and downwardly with respect to member 112. It is flexible bar coupling 230 that adsorbs this lateral motion and prevents it from being communicated to probe assembly 113 when Z tube 222 expands or contracts. Flexible bar coupling 230 has sufficient flexibility that it can deflect slightly from side to side throughout its length. It is provided with a length sufficient to permit these lateral deflections of the coupling 230 to occur without

introducing significant errors into the system. In this manner, member 112 is isolated from longitudinal motion of the piezoelectric actuator 110, but will communicate (X,Y) plane motions to flexure 232. Flexible bar coupling 230, flexure 232, and particularly link 232B are isolated from lateral movement generated by the expansion and contraction of Z tube 222, yet substantially duplicate the upward and downward motion of Z tube 222 and transmit it to probe assembly 113.

Please replace the paragraph beginning at page 44, paragraph [0075] with the following amended paragraph:

[0075] The scope of the application is not to be limited by the description of the preferred ~~I~~ embodiments described above, but is to be limited solely by the scope of the claims which follow.